ESP 121: Lab 3

Density dependence in continuous time and harvest

This lab focuses on the logistic model with constant-effort harvest:

$$\frac{dn}{dt} = rn\left(1 - \frac{n}{K}\right) - qen \tag{1}$$

where r is the population growth rate, K is the carrying capacity, and $h = qe$ is the per-capita harvest rate (catchability q multiplied by effort e). Solving $\frac{dn}{dt} = 0$, the nonzero equilibrium population size is:

$$\bar{n} = K\left(1 - \frac{qe}{r}\right). \tag{2}$$

Recall that, in class, we demonstrated graphically that the nonzero equilibrium is locally stable (and the zero equilibrium unstable) when it exists biologically (i.e., when the expression for $\bar{n}$ gives a positive value). If the above expression is negative, then $\bar{n} = 0$ is the locally stable equilibrium. We can then calculate the equilibrium biomass yield as the product of the harvest rate and the equilibrium population size: $\bar{Y} = qe\bar{n}$.

For this lab, run the `harvest.R` script to see four plots. The upper left-hand plot is the locally stable equilibrium population size $\bar{n}$ as a function of harvest rate, and upper right-hand plot is the corresponding equilibrium yield $\bar{Y}$. The two plots on the second row are time series (integrating $\frac{dn}{dt}$ to get n vs. t) given specific harvest rates that you can select; these are to help build your intuition of the model dynamics but are not necessary to answer the questions below. Each line in these plots represents a different time series with a different initial population size $n(0)$. As you adjust r and K to answer the questions below, pay careful attention to the y-axis values as well as how the shapes of the curves change.

1. What on these plots indicates h_{persist}, the maximum harvest rate that the population can sustain and still persist, and MSY, the maximum sustainable yield?

2. As you change r, what happens to each of h_{persist} and MSY (the harvest rate where you achieve MSY)? Why? For your answer here and in #3, be specific about directionality – e.g., increasing r increases/decreases/does not change each outcome – and put your explanation in biological terms.

3. As you change K, what happens to each of h_{persist} and MSY? Why?

4. If you were a manager assigned to determining how much you could sustainably harvest a fish population, which would you care more about measuring accurately, r or K? Why?